7.3.2 Gravitational potential

Gravitational potential (V) at a point in a gravitational field is defined as:
"the work done in moving a unit mass from infinity to that point"

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The only difference between gravitational potential and gravitational potential energy (E_{gp}) is that gravitational potential is the work done per unit mass (i.e. It is the gravitational potential energy a 1kg mass would have at that point.)

$$V = \frac{E_{gp}}{m}$$

where m is the mass in kg

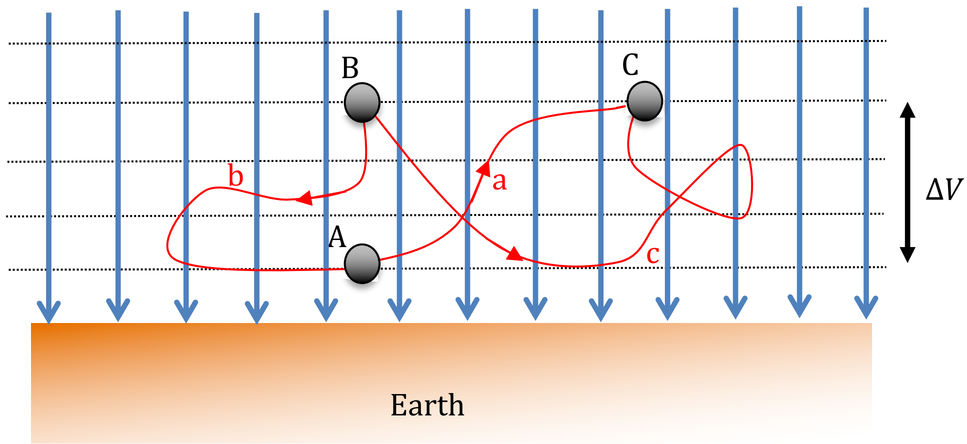
(1)✎What are the units for gravitational potential?

If we move a mass (m) from one position to another and there is a change in the gravitational potential (ΔV), then the change in gravitational potential energy is:

$$\Delta E_{gp} = m\Delta V$$

Uniform fields

In section 7.3.1 we saw that close the Earth's surface we can take the gravitational field to be (to a close approximation) uniform.



The dotted lines are called 'equipotential' lines. There is no change in gravitational potential along these lines.

(2)✎Would the change in gravitational potential energy be positive or negative when moving a mass from A to B?

The change in gravitational potential in moving from one point to another in a gravitational field is only dependent on the starting potential and the final potential and not on the path taken.

(3)✐Explain what changes (if any) occur to the gravitational potential energy of a mass moved along paths a, b, c, in the diagram above.

Radial fields

We saw in section 7.3.1 that the gravitational potential energy of a mass in a radial gravitational field is given by:

$$E_{gp} = -\frac{GMm}{r}$$

where G=the gravitational constant=$6.67 \times 10^{-11} m^3 kg^{-1} s^{-2}$*, and r=distance between the centre of mass of M and m*

(4)✐Using the equation at the top, write an expression for V, for a radial field.

(5)✐Work out the gravitational potential at the surface of the Earth.
$(radius\ of\ the\ Earth = 6400km, mass\ of\ Earth = 6.0 \times 10^{24} kg)$

(6)✐A geostationary orbit is found at a radius of 42000km. What is the gravitational potential at this position?

(7)✐What is the minimum energy required to launch 1kg to a geostationary orbit?

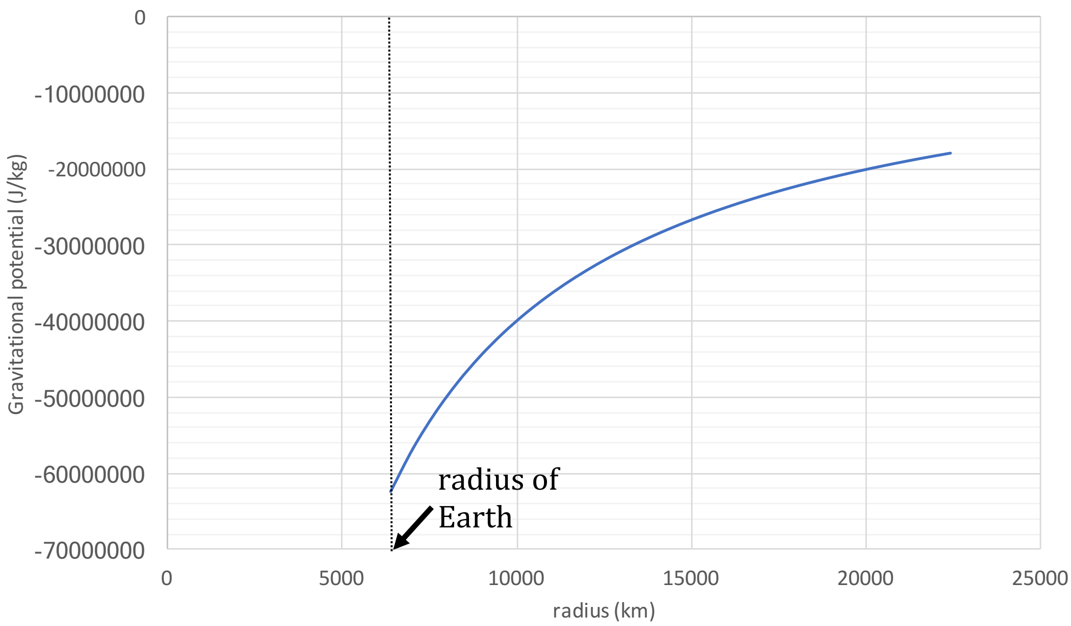
Gravitational field strength and gravitational potential

Gravitational field strength (g) is the gradient of the gravitational potential (V) versus radius (r) graph. Mathematically:

$$g = -\frac{\Delta V}{\Delta r}$$

Note: g is a vector quantity and V is a scalar quantity.

Consider the V versus r graph for the Earth:



The graph shows how the gravitational potential increases as you move away from the Earth's surface. The Earth's surface is at 6400km.

(8)✏Draw a tangent to the curve at 10000km and find the gradient.

(9)✏What is the gravitational field strength at 3600km above the Earth's surface? (Note: r on the graph is in km)